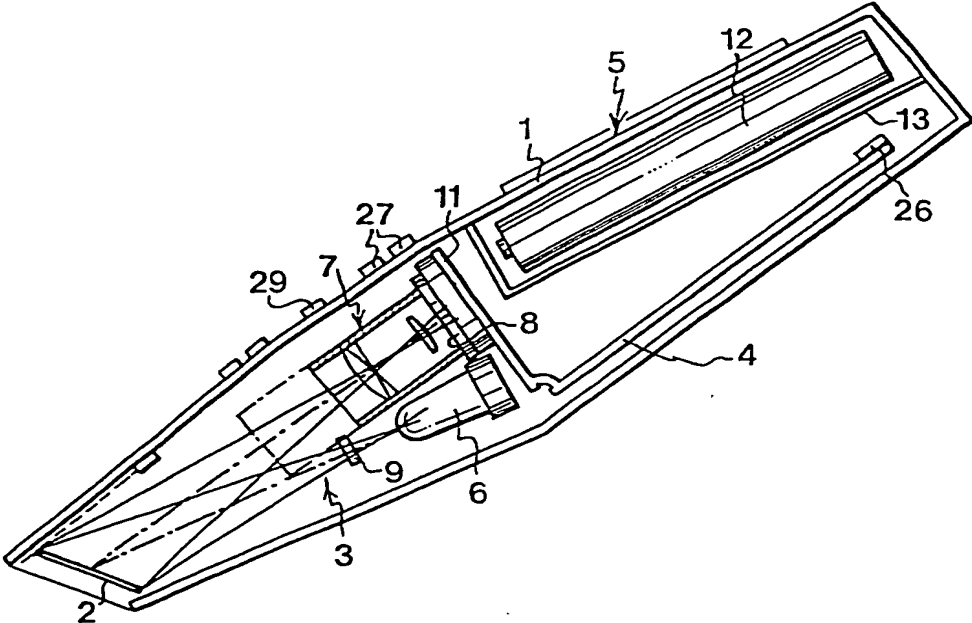


## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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| <p>(51) International Patent Classification <sup>6</sup> :<br/><b>G06F 3/033, G06K 11/18</b></p>  | <b>A1</b>                  | <p>(11) International Publication Number: <b>WO 99/60469</b></p> <p>(43) International Publication Date: 25 November 1999 (25.11.99)</p> |  |            |                          |    |            |                           |    |            |                            |    |   |                            |    |   |
| <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; vertical-align: top; padding: 5px;"> <p>(21) International Application Number: <b>PCT/SE99/00719</b></p> <p>(22) International Filing Date: 30 April 1999 (30.04.99)</p> <p>(30) Priority Data:</p> <table style="width: 100%; border: none;"> <tr> <td style="width: 30%;">9801535-7</td> <td style="width: 30%;">30 April 1998 (30.04.98)</td> <td style="width: 40%;">SE</td> </tr> <tr> <td>60/091,323</td> <td>30 June 1998 (30.06.98)</td> <td>US</td> </tr> <tr> <td>9803456-4</td> <td>9 October 1998 (09.10.98)</td> <td>SE</td> </tr> <tr> <td>60/105,816</td> <td>27 October 1998 (27.10.98)</td> <td>US</td> </tr> </table> <p>(71) Applicant (for all designated States except US): <b>C TECHNOLOGIES AB [SE/SE]; Forskningsbyn Ideon, S-223 70 Lund (SE).</b></p> <p>(72) Inventors; and</p> <p>(75) Inventors/Applicants (for US only): <b>FÅHRAEUS, Christer [SE/SE]; Sölvegatan 3, S-223 62 Lund (SE). HUGOSSON, Ola [SE/SE]; Sandgatan 14 B, S-223 50 Lund (SE). ERICSON, Petter [SE/SE]; Industrigatan 2 B, S-212 14 Malmö (SE).</b></p> <p>(74) Agent: <b>AWAPATENT AB; P.O. Box 5117, S-200 71 Malmö (SE).</b></p> </td> <td style="width: 50%; vertical-align: top; padding: 5px;"> <p>(81) Designated States: AE, AL, AM, AT, AT (Utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, EE (Utility model), ES, FI, FI (Utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).</p> <p><b>Published</b></p> <p><i>With international search report.</i></p> <p><i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p> <p><i>In English translation (filed in Swedish).</i></p> </td> </tr> </table> |                            |  | <p>(21) International Application Number: <b>PCT/SE99/00719</b></p> <p>(22) International Filing Date: 30 April 1999 (30.04.99)</p> <p>(30) Priority Data:</p> <table style="width: 100%; border: none;"> <tr> <td style="width: 30%;">9801535-7</td> <td style="width: 30%;">30 April 1998 (30.04.98)</td> <td style="width: 40%;">SE</td> </tr> <tr> <td>60/091,323</td> <td>30 June 1998 (30.06.98)</td> <td>US</td> </tr> <tr> <td>9803456-4</td> <td>9 October 1998 (09.10.98)</td> <td>SE</td> </tr> <tr> <td>60/105,816</td> <td>27 October 1998 (27.10.98)</td> <td>US</td> </tr> </table> <p>(71) Applicant (for all designated States except US): <b>C TECHNOLOGIES AB [SE/SE]; Forskningsbyn Ideon, S-223 70 Lund (SE).</b></p> <p>(72) Inventors; and</p> <p>(75) Inventors/Applicants (for US only): <b>FÅHRAEUS, Christer [SE/SE]; Sölvegatan 3, S-223 62 Lund (SE). HUGOSSON, Ola [SE/SE]; Sandgatan 14 B, S-223 50 Lund (SE). ERICSON, Petter [SE/SE]; Industrigatan 2 B, S-212 14 Malmö (SE).</b></p> <p>(74) Agent: <b>AWAPATENT AB; P.O. Box 5117, S-200 71 Malmö (SE).</b></p> | 9801535-7  | 30 April 1998 (30.04.98) | SE | 60/091,323 | 30 June 1998 (30.06.98)   | US | 9803456-4  | 9 October 1998 (09.10.98)  | SE | 60/105,816  | 27 October 1998 (27.10.98) | US | <p>(81) Designated States: AE, AL, AM, AT, AT (Utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, EE (Utility model), ES, FI, FI (Utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).</p> <p><b>Published</b></p> <p><i>With international search report.</i></p> <p><i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p> <p><i>In English translation (filed in Swedish).</i></p> |
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| <p>(54) Title: <b>CONTROL DEVICE AND METHOD OF CONTROLLING AN OBJECT</b></p>  |                            |  |  |            |                          |    |            |                           |    |            |                            |    |   |                            |    |   |
|   |                            |  |  |            |                          |    |            |                           |    |            |                            |    |   |                            |    |   |
| <p>(57) Abstract</p> <p>A control device, for example a computer mouse, has image-recording means which are adapted to be moved, preferably manually, for controlling an object, for example a cursor on a computer screen, as a function of the movement of the image-recording means. The control device is adapted to record a plurality of images with partially overlapping contents when the image-recording means are being moved, the partially overlapping contents of the images enabling image-processing means to generate control signals indicating how the image-recording means have been moved. A method of controlling and a control device based on the turning of the image-recording means are also shown.</p>   |                            |  |  |            |                          |    |            |                           |    |            |                            |    |   |                            |    |   |

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CONTROL DEVICE AND METHOD OF CONTROLLING AN OBJECTField of the Invention

The present invention relates to a control device having image-recording means which are adapted to be moved, preferably manually, for controlling an object as a function of the movement of the image-recording means.

5 The invention also relates to a method of controlling an object.

Background of the Invention

Today, personal computers are usually equipped with a control device, a so-called computer mouse, which is  
10 used for positioning a cursor on the computer screen. The positioning is carried out by the user passing the mouse over a surface, the hand movement indicating how the mouse should be positioned. The mouse generates positioning signals indicating how the mouse has been moved and  
15 thus how the cursor should be moved. Presently, the most common type of mouse has a ball on its underside, which turns as a result of friction against the surface when the mouse is passed over the same and which in this connection drives position sensors which in turn generate  
20 the positioning signals. Normally, the mouse can also be used for providing instructions to the computer by the intermediary of one or more buttons on which the user clicks.

Optical computer mice are also known. JP 09190277  
25 shows an optical mouse having one CCD line sensor for the X-axis and one CCD line sensor for the Y-axis. Data recorded by means of the CCD line sensors at a certain time is compared with data recorded at a subsequent time, whereby the movement of the mouse in the X direction and  
30 in the Y direction can be determined.

A mouse is thus used for controlling a virtual object. However, there are other control devices whose

structure is similar to that of a mouse, but which are used for controlling physical objects instead.

Furthermore, there are control devices for controlling objects in two dimensions, i.e. in a plane, or in  
5 three dimensions, i.e. in a space.

WO 98/11528 describes a control device which provides a computer with three-dimensional information. The device is based on three accelerometers which are placed in mutually perpendicular directions and which are capable of measuring acceleration or inclination in one to  
10 three directions. The device can, for example, be placed on the user's head or it can be hand-held.

A computer mouse for inputting three-dimensional information to a computer is described in US Patent  
15 5,506,605. This computer mouse is hand-held and is intended to be held freely in space. Furthermore, it can comprise sensors for measuring various physical properties which are subsequently interpreted by suitable electronic means, converted into digital format, and input  
20 to the computer. The position of the mouse in space is determined by position sensors, which may be based on light, acceleration, gyroscopes, etc. In the embodiment described, use is made of an ultrasonic sensor and a magnetic sensor. On the basis of the input, the computer  
25 can subsequently generate tactile feedback in the form of vibrations which, for example, provide the user with information concerning the location of the mouse in relation to its desired location.

#### Summary of the Invention

30 It is an object of the present invention to provide an improved control device and an improved method of controlling an object which are suited for both two-dimensional and three-dimensional control of physical as well as virtual objects.

35 This object is achieved by control devices according to claims 1 and 23 and by a method according to claim 24. Preferred embodiments are stated in the subclaims.

Thus, according to a first aspect, the invention relates to a control device having image-recording means which are adapted to be moved by a user, preferably manually, for controlling an object, which may be physical or virtual, as a function of the movement of the image-recording means. The image-recording means are adapted to record a plurality of images with partially overlapping contents when they are being moved, the partially overlapping contents enabling the determination of how the image-recording means have been moved.

The invention is thus based on the idea of using images for determining how a unit is being moved. This technology can be used for two-dimensional as well as three-dimensional control. It is advantageous because it requires few sensors and no moving parts. The entire movement information is contained in the overlapping contents of the images. Because the device records images of the surroundings, an "absolute" position indication is obtained, making it possible to detect when the image-recording means are in a specific position, which, for example, is not possible when using control devices based on measuring acceleration. In addition to movement, turning can also be detected and used for controlling an object.

In one embodiment, the control device is designed for controlling an object in a plane. In this case, the overlapping images enable the determination of not only the movement of the image-recording means but also their turning in the plane, which, for example, is not possible when using a traditional mouse with a ball. Accordingly, the control device is advantageously adapted to control the angular position of the object in the plane. When the device is designed for control in a plane, the image-recording means are advantageously provided with a light-sensitive sensor means having a two-dimensional sensor surface, a so-called area sensor, for recording the images. In this context, a two-dimensional sensor sur-

face refers to the fact that the sensor surface must be capable of imaging a surface with a matrix of pixels. CCD sensors and CMOS sensors are examples of suitable sensors. A single sensor is thus sufficient for providing control in a plane.

In an alternative embodiment, the device is designed for controlling an object in a space. In this case, too, the control device is advantageously adapted to control the angular position of the object, in which connection the control can take place about three axes. In an economical embodiment, it may be sufficient for the device to have two light-sensitive sensors each having a two-dimensional sensor surface for recording said images in two different directions.

However, for more precise control in space, it is preferable for the image-recording means to comprise three sensors for recording the images in three, preferably perpendicular, directions. This enables the determination of the translation along three mutually perpendicular axes as well as of the rotation about these axes by means of relatively simple calculations.

Suitably, the control device has image-processing means for providing control signals for controlling the object. The image-processing means may be located in the same physical casing as the image-recording means, the output signals from this physical casing thus constituting the control signals for controlling the object which is to be controlled. However, the image-processing means may also be located in another physical casing, for example in a computer whose cursor constitutes the object which is to be controlled, or in a computer which in turn controls, or forms part of, a physical object which is controlled by means of the control device, the output signals from the image-processing means constituting the control signals for controlling the object. In this context, it should be noted that the control signals outputted from the image-processing means may require further

processing before they can be used for direct control of the object. The image-processing means are advantageously implemented with the aid of a processor and software, but can also be implemented completely with the aid of hardware.

The image-processing means are suitably adapted to determine the relative positions of the images with the aid of the partially overlapping contents for providing said control signals. If the control device is used for control in three dimensions, this is suitably carried out in parallel with respect to all the sensors. The distance and direction of the movement, and thus the current position, can be determined on the basis of the relative positions of the images.

Advantageously, the control device has a calibration mode, in which the image-recording means are moved in a way that enables the image-processing means to relate the relative positions of the images to an actual movement of the image-recording means. As an alternative, the control device could be provided with a distance meter measuring the distance to the surfaces being imaged with the aid of the sensors, but that would, of course, be more expensive.

The image-processing means are suitably adapted to generate said control signals on the basis of at least one movement vector obtained from the relative positions of the images.

Additionally, or alternatively, the image-processing means may be adapted to generate said control signals on the basis of at least one turning indication obtained from the relative position of the images. The control signals can thus be used for controlling the turning of an object as well as its movement, which is an advantage compared to traditional mechanical computer mice.

In the case of a control device for three-dimensional control, the image-processing means can combine information from all the sensors with respect to the

relative positions of the images in order to generate one movement vector and one turning vector. In this way, the position of the image-recording means can be unambiguously determined. In other words, the control device can  
5 carry out a digitisation of the movement performed by a hand when it moves the image-recording means in order to enable a computer to control an object on the basis of this movement.

In one embodiment, the image-processing means may be  
10 adapted to generate said control signals on the basis of the speed at which the image-recording means have been moved, the speed being determined from the relative positions of the images and the image-recording frequency.

Suitably, the receiver of the control signals should  
15 know that the control signals are control signals so that it will know how the signals are to be subsequently processed. Consequently, the image-processing means are preferably adapted to output said control signals in such a way that a receiver can identify the control signals as  
20 being intended for controlling an object. This can, for example, be effected by the use of a predetermined protocol.

An advantage of using an image-based control device is that it becomes possible to determine when the image-  
25 recording means are in a predetermined position, since this position can be defined by means of one or several images. For example, it is possible to detect when the image-recording means have returned to their original position. For this purpose, the image-processing means  
30 are adapted to store at least one reference image and to compare images recorded subsequently with this image in order to generate a signal in the case of an essentially complete overlap. For instance, the user can define a certain position as a reference position by clicking on  
35 the control device in this position.

If the image-recording means and the image-processing means are located in different physical casings,



the image-recording means may advantageously comprise a transmitter for wireless transmission of images from the image-recording means to the image-processing means. Moreover, especially if the image-recording and the image-processing means are located in the same physical casing, it may be an advantage if the image-processing means comprise a transmitter for wireless outputting of the control signals, for example to a computer whose cursor is to be controlled. In both cases, the control device is very easy to use since no flex is required for the information transfer. For example, a user can have a personal image-recording means or control device and use it with different computers or receivers of the control signals. The transmitter can be an IR transmitter, a radio transmitter, which, for example, uses the so-called Bluetooth standard, or some other transmitter which is suitable for wireless information transfer between two units located fairly close to each other.

In a preferred embodiment, the control device is a computer mouse, i.e. a device which can be connected to a computer and be used for positioning a cursor in one, two, or several dimensions.

The control device can be used in a first absolute mode or in a second relative mode. In the absolute mode, the movement of the controlled object is proportional to the movement of the image-recording means. In other words, the object moves in a way that corresponds to the movement of the image-recording means, regardless of where these are located. In the relative mode, however, the control device is configured so that the speed or acceleration of the controlled object increases when the distance increases between the image-recording means and a predefined origin of coordinates. In this way, it becomes possible to achieve faster movement of the object by holding the image-recording means farther away from the predefined origin, while, at the same time, precision

control can be achieved by holding the image-recording means closer to the origin.

According to a second aspect of the invention, it relates to a control device having image-recording means which are adapted to be turned, preferably manually, for controlling an object as a function of the turning of the image-recording means. The control device is adapted to record a plurality of images with partially overlapping contents when the image-recording means are being turned, the partially overlapping contents of the images enabling the determination of how the image-recording means have been turned.

This control device is thus based on the same idea as the control device described above, but instead of controlling the object as a function of the movement of the image-recording means, it is controlled as a function of their turning. This control device may, for example, be a trackball. The embodiments discussed above are to a large extent also applicable to the turning control device, and the same advantages are obtained.

According to a third aspect of the invention, it relates to a method of controlling an object, comprising the steps of moving a control device; recording, with the aid of the control device, a plurality of images with overlapping contents during the movement of the control device; and determining the movement of the control device with the aid of the contents of the overlapping images. The same advantages are obtained as those described with respect to the above-mentioned devices.

### Brief Description of the Drawings

The present invention will be described in more detail below by way of exemplifying embodiments with reference to the accompanying drawings, in which

Fig. 1 schematically shows an embodiment of a control device according to the invention;

Fig. 2 is a block diagram of the electronic circuitry part of an embodiment of the control device according to the invention;

Fig. 3 schematically shows a second embodiment of a control device according to the invention;

Fig. 4 is a flowchart illustrating the operation of a control device for two-dimensional control;

Fig. 5 schematically shows an "open box" in which the control device in Fig. 3 can be used;

Fig. 6 schematically shows a movement of the control device according to the invention from a point  $(x,y,z)$  to a point  $(x+\delta x,y+\delta y,z+\delta z)$  in an orthonormal coordinate system with the axes  $e_x$ ,  $e_y$ , and  $e_z$ ;

Fig. 7 schematically shows which translation scalars are outputted from the respective sensors when the control device is being moved (index shows which sensor is generating the respective scalars); and

Fig. 8 schematically shows how the control device is intended to be moved in the calibration mode.

#### Description of Preferred Embodiments

The control device according to the invention can be implemented in embodiments of essentially two main types. A first embodiment of the control device according to the invention will be described below, which embodiment is intended to be used as a two-dimensional mouse. Next, a second embodiment of the control device will be described, which embodiment is intended to be used as a three-dimensional mouse. Finally, the operation of the two-dimensional and the three-dimensional mouse will be described. In both embodiments described, the image-recording means and the image-processing means are located in the same physical casing, from which control signals are outputted. As mentioned above, the image-processing means can also be located in a separate physical casing. It is very simple for the skilled person to carry out this modification.

Design of the Control Device

In the first embodiment of the control device shown in Fig. 1, it comprises a casing 1 having approximately the same shape as a conventional highlighter pen. One short side of the casing has a window 2, by the intermediary of which images are read into the device. The window 2 is somewhat recessed in the casing in order not to wear against the underlying surface.

The casing 1 essentially contains an optics part 3, an electronic circuitry part 4, and a power supply part 5.

The optics part 3 comprises a light-emitting diode 6, a lens system 7, and image-recording means in the form of a light-sensitive sensor 8, which constitutes the interface with the electronic circuitry part 4.

The task of the LED 6 is to illuminate a surface which is currently located under the window in the case where the control device is held directly against a surface or very close thereto. A diffuser 9 is mounted in front of the LED 6 for diffusing the light.

The lens system 7 has the task of projecting an image of the surface located under the window 2 onto the light-sensitive sensor 8 as accurately as possible.

In this example, the light-sensitive sensor 8 comprises a two-dimensional, square CCD unit (CCD = charge coupled device) with a built-in A/D converter. Such sensors are commercially available. The sensor 8 is mounted at a small angle to the window 2 and on its own circuit board 11.

The power supply to the control device is obtained from a battery 12, which is mounted in a separate compartment 13 in the casing.

The block diagram in Fig. 2 schematically shows the electronic circuitry part 4. This is located on a circuit board and comprises a processor 20, which by the intermediary of a bus 21 is connected to a ROM 22, in which the programs of the processor are stored, to a read/write

memory 23, which constitutes the working memory of the processor and in which the images from the sensor are stored, to a control logic unit 24, as well as to the sensor 8 and the LED 6. The processor 20, the bus 21, the memories 22 and 23, the control logic unit 24, as well as the associated software together constitute image-processing means.

The control logic unit 24 is in turn connected to a number of peripheral units, comprising a radio transceiver 26 for transferring information to/from an external computer, buttons 27, by means of which the user can control the image-recording means and which can also be used as the clicking buttons of a traditional mouse, as well as an indicator 29, e.g. a LED, indicating when the mouse is ready to be used. Control signals to the memories, the sensor, and the peripheral units are generated in the control logic unit 24. The control logic also handles generation and prioritisation of interrupts to the processor. The buttons 27, the radio transceiver 26, and the LED 6 are accessed by the processor writing and reading in a register in the control logic unit 24. The buttons 27 generate interrupts to the processor 20 when they are activated.

Fig. 3 shows a second embodiment of the control device according to the invention. Like the first embodiment, this embodiment comprises a pen-shaped casing 31. Besides the window 32 on one short side of the casing, the device has two additional windows 32' and 32". Each of the windows 32, 32', 32" is somewhat recessed in the casing so that it will not wear or scratch should the control device impinge upon a surface when it is in use, or when it is in the idle position.

As in the above case, the casing 1 essentially contains an optics part 33, an electronic circuitry part 34, and a power supply part 5.

The optics part 33 comprises a lens package (not shown) with three lens systems and a set of sensors (not

shown) with three light-sensitive sensors which constitute the interface to the electronic circuitry part 34 for the windows 32, 32' and 32" respectively. There is no light-emitting diode in this embodiment. The control device is intended to be held at a distance from the surfaces which are being imaged and, consequently, in most cases, ambient light is sufficient to permit images to be recorded.

The lens systems have the task of projecting images of the surfaces at which the windows 32, 32', 32" are directed onto the light-sensitive sensors as accurately as possible.

As in the above embodiment, the light-sensitive sensors comprise two-dimensional, square CCD units with built-in A/D converters. Each sensor is mounted on its own circuit board.

In this embodiment, too, the power supply to the control device is obtained from a battery, which is mounted in a separate compartment in the casing.

In this second embodiment, the design of the electronic circuitry part is essentially the same as that described above with respect to the first embodiment. The electronic circuitry part is shared by all three sensors.

Application of the Device as a Two-dimensional Mouse

The device according to the first embodiment can be used as a mouse for inputting movement information, by means of which a cursor can be controlled on a computer screen.

The user directs the window 2 of the control device at a patterned surface, e.g. a mouse pad. He presses one of the buttons 27 to activate the image-recording means, whereupon the processor 20 commands the LED 6 to begin generating strobe pulses at a predetermined frequency, suitably at least 50 Hz. Subsequently, the user passes the control device over the surface in the same way as if it were a traditional mouse, whereupon images with partially overlapping contents are recorded by the sensor

8 and stored in the read/write memory 23. The images are stored as images, i.e. with the aid of a plurality of pixels, each having a grey scale value in a range from white to black.

5       The flowchart in Fig. 4 shows the operation of the two-dimensional mouse in more detail. In step 400, a starting image is recorded. In step 401, the next image is recorded. The contents of this image partially overlap the contents of the previous image.

10       As soon as an image has been recorded in step 401, the process begins of determining how it overlaps the previous image, step 402, i.e. in which relative position the best match is obtained between the contents of the images. This determination is carried out by translating  
15 the images vertically and horizontally relative to each other, and by rotating the images relative to each other. For this purpose, every possible overlap position between the images is examined, at the pixel level, and an overlap measurement is determined as follows:

20       1) For each overlapping pixel position, the grey scale values of the two relevant pixels are added up if the latter are not white. Such a pixel position in which none of the pixels is white is designated a plus position.

25       2) The grey scale sums for all the plus positions are added up.

30       3) The neighbours of each pixel position are examined. If an overlapping pixel position is not a neighbour of a plus position and consists of a pixel which is white and a pixel position which is not white, the grey scale value of the non-white pixel is subtracted, possibly multiplied by a constant, from the sum in point 2).

4) The overlap position providing the highest overlap measurement as stated above is selected.

35       Our Swedish patent application No. 9704924-1 and the corresponding U.S. application No. 024 641 describe an alternative way of matching the images in order to find

the best overlap position. The content of these applications is herewith incorporated by reference.

As soon as the best overlap position between the current image and the previous image has been determined, the previous image is discarded, whereupon the current image becomes the previous image in relation to the next image recorded.

By determining the relative position of the two images a movement vector is obtained, which indicates how far and in which direction the image-recording means have been moved between the recording of the two images. If the mouse has also been turned between the two images, also a measurement of this turning is obtained. Subsequently, a control signal, which includes the movement vector and the measurement of turning, is transmitted, step 403, by the radio transceiver 26 to the computer for which the control device is operating as a mouse. The computer uses the movement vector and the measurement of turning for positioning the cursor on its screen. Subsequently, the flow returns to step 401. In order to increase the speed, the steps can be partly carried out in parallel, e.g. by starting the recording of the next image while the current image is being put together with the previous image.

When the mouse is activated, the buttons 27 can be used as clicking buttons for inputting instructions to the computer.

#### Application of the Device as a Three-dimensional Mouse

The device according to the second embodiment can be used as a mouse for inputting movement information, by means of which a cursor can be controlled in three dimensions on a computer screen, i.e. in a space.

As described above, the three-dimensional mouse comprises three sensors 32, 32', 32" having two-dimensional, light-sensitive sensor surfaces. The main axes of the sensors are orientated along the x-, y-, and z-axes in an orthogonal coordinate system and have a two-dimensional



spatial resolution of  $n \times n$  pixels and a time resolution of  $m$  images per second. Each lens system provides a field of vision with an angle of vision of  $v$  radians for the associated sensor surface.

5       When the device is in use, the mouse movements are carried out in an "open box" 50 according to Fig. 5, which is defined by at least two side walls 51 and 52 which are orientated at right angles in relation to each other, and a floor 53. It is also possible that the mouse  
10       can be held freely in space, but this requires more complicated calculation algorithms than the ones that will be described below.

      When the device is in use, the above method of determining the relative position of images is used for  
15       each sensor. Accordingly, the operation in this case can also be described by means of the flowchart in Fig. 4, but instead of recording individual images, a set of images consisting of three images is recorded simultaneously. One movement vector and one turning vector are  
20       thus generated with the aid of the images recorded by each light-sensitive sensor, which vectors describe the movement carried out by the mouse between the recording of two consecutive images. These vectors are then included in a control signal which is transmitted to the object  
25       which is to be controlled by means of the mouse.

      Furthermore, to enable the successful use of the mouse, it is necessary that the light conditions be such that the light-sensitive sensors are capable of recording images of sufficiently high quality to permit their processing as described above.  
30

      In order further to facilitate the reader's understanding of how the movement of the mouse can control the object, a description of the calculations carried out to determine the movement of the mouse will now be provided  
35       by way of example, with reference to Fig. 6. In the calculations below it is assumed that the image-matching algorithm is of a simple type which for each sensor mere-

ly calculates the translation in two mutually perpendicular directions between two images. Suppose that the mouse is located in the position  $(x, y, z)$  and that it has a rotation which can be described by means of the orthogonal rotation matrix  $R$ . The x-axis of the mouse thus points in the direction  $R \cdot e_x$ , the y-axis points in the direction  $R \cdot e_y$ , and the z-axis points in the direction  $R \cdot e_z$ . Also suppose that between the recording of two images, the mouse carries out a translational motion and/or a rotational motion according to:

$$(x, y, z) \rightarrow (x + \delta x, y + \delta y, z + \delta z)$$

$$R \rightarrow R \cdot \delta R$$

In the local coordinate system of the mouse, the translation vectors can be defined as shown in Fig. 7. The first sensor records movements in the x and y directions, the second sensor records movements in the y and z directions, and the third sensor records movements in the x and z directions. Consequently, for any triplet of consecutive images, the translation scalars  $(x_1, y_1, y_2, z_2, x_3, z_3)$  describe the detected movement of the mouse. The translation scalars consist of the outputs from the image-matching algorithm for each sensor.

In order to calculate the rotation of the mouse, the effect of a rotation upon the translation scalars is calculated. Suppose that the mouse is rotated through an angle  $\alpha$ , which is sufficiently small so that  $\sin \alpha \cong \alpha$ . For the sake of clarity, it is also assumed that the rotation takes place about the z-axis by  $\alpha_z$  radians. This rotation results in the scalars

$$y_2 = \frac{n}{v} \alpha_z \text{ and } x_3 = -\frac{n}{v} \alpha_z$$

where  $n$  is the number of pixels along one side of the sensor and  $v$  is the angle of vision of the sensor surface, expressed in radians. Thus, the following applies to all the axes:

$$\begin{matrix}
 & & 17 \\
 & & \begin{bmatrix} 0 & -\frac{n}{v} & 0 \\ \frac{n}{v} & 0 & 0 \\ 0 & 0 & \frac{n}{v} \\ 0 & -\frac{n}{v} & 0 \\ 0 & 0 & -\frac{n}{v} \\ \frac{n}{v} & 0 & 0 \end{bmatrix} \begin{bmatrix} \alpha_x \\ \alpha_y \\ \alpha_z \end{bmatrix} = \begin{bmatrix} x1 \\ y1 \\ y2 \\ z2 \\ x3 \\ z3 \end{bmatrix}
 \end{matrix}$$

By knowing the values of the translation scalars, which are output signals from the image-matching algorithm, the number of pixels  $n$  of the sensor surface along one side and the angle of vision  $v$  of the sensor, it is thus possible to calculate a rotation vector  $(\alpha_x, \alpha_y, \alpha_z)$  for the rotation of the mouse about the x-, y- and z-axes.

Furthermore, in order to calculate the translational motion one must know the functional distance from each sensor to the ambient geometry. The functional distance is a constant which relates the output from the image-matching algorithm to the translational motion. The functional distance is determined by means of a calibration which will be described below. In the special case where the mouse moves inside an "open box" 50 as described above, the functional distance corresponds to the geometrical distance from the middle of the mouse to the respective walls 51, 52, and 53 of the box 50.

For the sake of clarity, a translation of a distance  $\delta x$  along the x-axis is looked at. Accordingly, the effect of the translation with respect to the scalars  $x1$  and  $x3$  will be respectively

$$x1 = \frac{n}{2d_1 \tan \frac{v}{2}} \delta x$$

and

$$x_3 = \frac{n}{2d_3 \tan \frac{\nu}{2}} \delta x$$

Here,  $d_1$  and  $d_3$  are the functional distances from the  
 5 mouse to the projected surfaces with respect to  $(x_1, y_1)$   
 and  $(x_3, z_3)$ . The following is obtained if this is generalised to all the axes

$$\begin{bmatrix} \frac{n}{2d_1 \tan \frac{\nu}{2}} & 0 & 0 \\ 0 & \frac{n}{2d_1 \tan \frac{\nu}{2}} & 0 \\ 0 & \frac{n}{2d_2 \tan \frac{\nu}{2}} & 0 \\ 0 & 0 & \frac{n}{2d_2 \tan \frac{\nu}{2}} \\ \frac{n}{2d_3 \tan \frac{\nu}{2}} & 0 & 0 \\ 0 & 0 & \frac{n}{2d_3 \tan \frac{\nu}{2}} \end{bmatrix} \begin{bmatrix} \delta x \\ \delta y \\ \delta z \end{bmatrix} = \begin{bmatrix} x_1 \\ y_1 \\ y_2 \\ z_2 \\ x_3 \\ z_3 \end{bmatrix}$$

10

By knowing the values of the translation scalars,  
 which are obtained as output signals from the image-  
 matching algorithm, the number of pixels  $n$  of the sensor  
 surface along one side, the field of vision  $\nu$  of the sen-  
 15 sor and the functional distances  $d_1$ -  $d_3$  to the projected  
 surfaces, it is thus possible to calculate a translation  
 vector  $(\delta x, \delta y, \delta z)$  for the translation of the mouse along  
 the  $x$ -,  $y$ - and  $z$ -axes.

To sum up, the translation scalars  $(x_1, y_1, y_2, z_2,$   
 20  $x_3, z_3)$  which are obtained in the image matching, thus  
 depend on the rotation as well as translation of the

mouse. Knowing these and other parameters described above, a translation vector  $(\delta x, \delta y, \delta z)$  and a rotation vector  $(\alpha_x, \alpha_y, \alpha_z)$  can be obtained by solving the following system of equations, which is solvable. These vectors are then included in a control signal which is transmitted to the object controlled by means of the mouse, which signal indicates the new position of the object.

$$\begin{bmatrix} \frac{n}{2d_1 \tan \frac{\nu}{2}} & 0 & 0 & 0 & -\frac{n}{\nu} & 0 \\ 0 & \frac{n}{2d_1 \tan \frac{\nu}{2}} & 0 & \frac{n}{\nu} & 0 & 0 \\ 0 & \frac{n}{2d_2 \tan \frac{\nu}{2}} & 0 & 0 & 0 & \frac{n}{\nu} \\ 0 & 0 & \frac{n}{2d_2 \tan \frac{\nu}{2}} & 0 & -\frac{n}{\nu} & 0 \\ \frac{n}{2d_3 \tan \frac{\nu}{2}} & 0 & 0 & 0 & 0 & -\frac{n}{\nu} \\ 0 & 0 & \frac{n}{2d_3 \tan \frac{\nu}{2}} & \frac{n}{\nu} & 0 & 0 \end{bmatrix} \begin{bmatrix} \delta x \\ \delta y \\ \delta z \\ \alpha_x \\ \alpha_y \\ \alpha_z \end{bmatrix} = \begin{bmatrix} x1 \\ y1 \\ y2 \\ z2 \\ x3 \\ z3 \end{bmatrix}$$

10

Calibration, i.e. the calculation of the functional distances  $d_1$ ,  $d_2$ , and  $d_3$ , can be carried out by moving the mouse along the edges of the open box. The mouse is moved along the x-, y-, and z-axes according to a sequence A-B-C shown in Fig. 8. Each movement gives rise to two equations, which together give the following system of equations:

15

$$\begin{cases} d_1 - 0,5 = \frac{n}{2x_1 \tan \frac{\nu}{2}} \\ d_3 + 0,5 = \frac{n}{2x_3 \tan \frac{\nu}{2}} \end{cases} \quad \begin{cases} d_2 - 0,5 = \frac{n}{2y_2 \tan \frac{\nu}{2}} \\ d_1 - 0,5 = \frac{n}{2y_1 \tan \frac{\nu}{2}} \end{cases} \quad \begin{cases} d_2 - 0,5 = \frac{n}{2z_2 \tan \frac{\nu}{2}} \\ d_3 - 0,5 = \frac{n}{2z_3 \tan \frac{\nu}{2}} \end{cases}$$

This overdefined system of equations contains all the information required to calculate the values of the functional distances  $d_1$ ,  $d_2$ , and  $d_3$ .

Furthermore, by means of the mouse according to this embodiment, the user can choose at a certain time to store the images which the sensors are currently recording in a memory. Subsequently, each set of recorded images is compared to the stored set of images and when a complete overlap exists, a signal is generated to the user. This enables precision control of an object since the user can find his way back to the exact position at which the mouse was located on a previous occasion. Naturally, the same principles can be used in the case of two-dimensional control of an object.

In another application of the mouse, only the rotational motion is detected. In this case, no calibration is required and it is sufficient to solve the equation presented above in connection with the discussion concerning rotation. In this application, the mouse can, for example, be mounted on a helmet or the like which is worn by the user and which, for example, is used in various types of virtual reality applications.

## CLAIMS

1. A control device having image-recording means  
5 which are adapted to be moved, preferably manually, for  
controlling an object as a function of the movement of  
the image-recording means; c h a r a c t e r i s e d in  
that the control device is adapted to record a plurali-  
10 ty of images with partially overlapping contents when  
the image-recording means are being moved, the partially  
overlapping contents of the images enabling the determi-  
nation of how the image-recording means have been moved.
2. A control device according to claim 1, wherein  
the control device is adapted to control said object in  
15 a plane.
3. A control device according to claim 2, wherein  
the control device is adapted to control the angular  
position of said object in said plane.
4. A control device according to claim 2 or 3,  
20 further comprising a light-sensitive sensor means (8)  
having a two-dimensional sensor surface for recording  
the images.
5. A control device according to claim 1, wherein  
the control device is designed for controlling said  
25 object in a space.
6. A control device according to claim 5, wherein  
the control device is adapted to control the angular  
position of said object in said space.
7. A control device according to claim 5 or 6,  
30 further comprising at least two light-sensitive sensor  
means (8) having a two-dimensional sensor surface for  
recording said images in two different directions.
8. A control device according to claim 5 or 6,  
further comprising three light-sensitive sensor means  
35 (3) having a two-dimensional sensor surface for record-  
ing said images in three linearly independent directions.

9. A control device according to any one of claims 1-8, further comprising image-processing means (20-24) for providing control signals for controlling said object.

5        10. A control device according to claim 9, wherein the image-processing means (20-24) are adapted to determine the relative positions of the images with the aid of the partially overlapping contents for providing said control signals.

10       11. A control device according to any one of claims 5-8, further comprising image-processing means (20-24) which are adapted to determine the relative positions of the images with the aid of the partially overlapping contents simultaneously with respect to all the light-sensitive sensor means (8) for providing said control signals.

15       12. A control device according to claim 11, the control device furthermore having a calibration mode, in which the image-recording means are moved in a way that enables the image-processing means (20-24) to relate the relative positions of the images to an actual movement of the image-recording means.

20       13. A control device according to any one of claims 10-12, wherein the image-processing means (20-24) are adapted to generate said control signals on the basis of at least one movement vector obtained from the relative positions of the images.

25       14. A control device according to any one of claims 10-13, wherein the image-processing means (20-24) are adapted to generate said control signals on the basis of at least one turning indication obtained from the relative positions of the images.

30       15. A control device according to any one of claims 10-14, wherein the image-processing means (20-24) are adapted to generate said control signals on the basis of the speed at which the image-recording means have been moved, the speed being determined from the relative positions of the images.



16. A control device according to claims 9-15,  
wherein the image-processing means (20-24) are adapted  
to output said control signals in a way that enables a  
receiver to identify the control signals as being intend-  
5 ed for controlling an object.

17. A control device according to any one of claims  
9-16, wherein the image-processing means (20-24) are fur-  
thermore adapted to store at least one reference image  
and to compare images recorded subsequently with that  
10 image in order to generate a signal in the case of an  
essentially complete overlap.

18. A control device according to any one of claims  
9-17, wherein the image-processing means (20-24) comprise  
a transmitter (26) for wireless outputting of the control  
15 signals.

19. A control device according to any one of claims  
9-18, wherein the image-recording means comprise a trans-  
mitter (26) for wireless transmission of images to the  
image-processing means (20-24).

20. A control device according to any one of the  
preceding claims, wherein the control device is a mouse.

21. A control device according to any one of the  
preceding claims, wherein the device has a first operat-  
ing mode in which the control device is adapted to con-  
25 trol said object in a way that enables its movement to  
be proportional to the movement of the image-recording  
means.

22. A control device according to any one of the  
preceding claims, wherein the device has a second operat-  
30 ing mode in which the control device is adapted to con-  
trol said object so that the speed of its movement is  
proportional to the distance between the image-recording  
means and a predefined origin.

23. A control device having image-recording means  
35 which are adapted to be turned, preferably manually, for  
controlling an object as a function of the turning of the  
image-recording means; c h a r a c t e r i s e d in that

the control device is adapted to record a plurality of images with partially overlapping contents when the image-recording means are being turned, the partially overlapping contents of the images enabling the determination of how the image-recording means have been turned.

24. A method of controlling an object, comprising the steps of

- moving a control device;
- recording, with the aid of the control device, a plurality of images with overlapping contents during the movement of the control device, and

- determining the movement of the control device with the aid of the contents of the overlapping images.

25. A method of controlling an object according to claim 24, further comprising the step of

- determining the relative position of the images with the aid of the partially overlapping contents for providing control signals for controlling the object.

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FIG.1

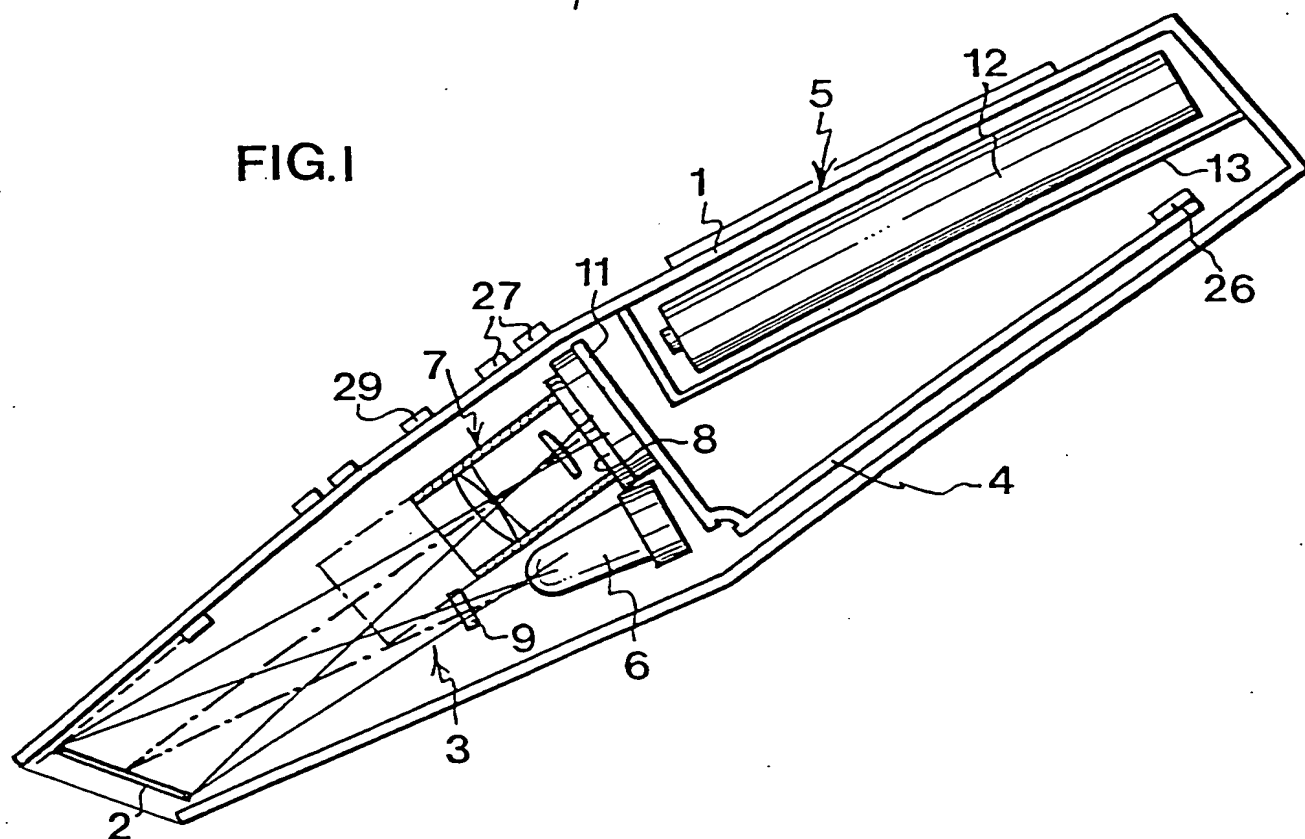
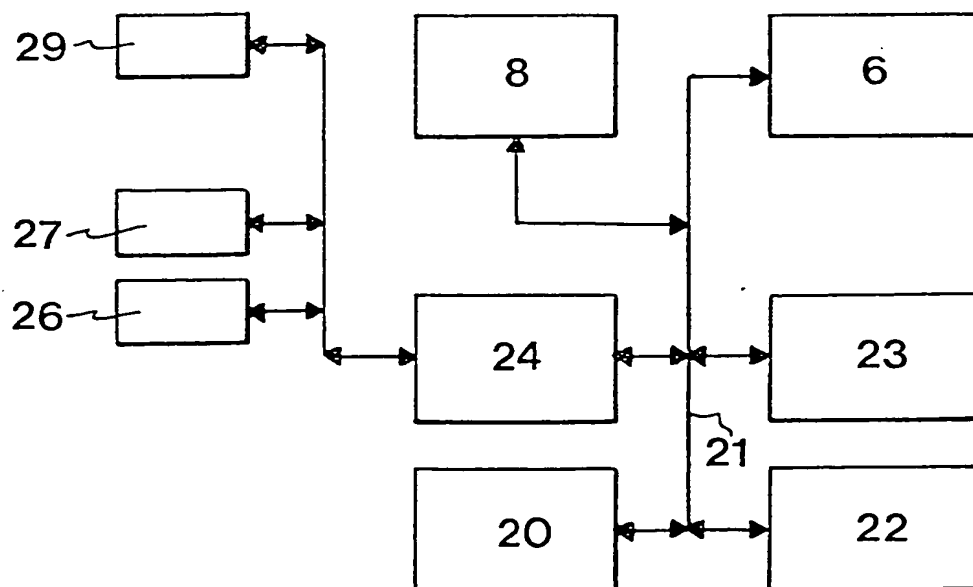


FIG.2



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FIG 3

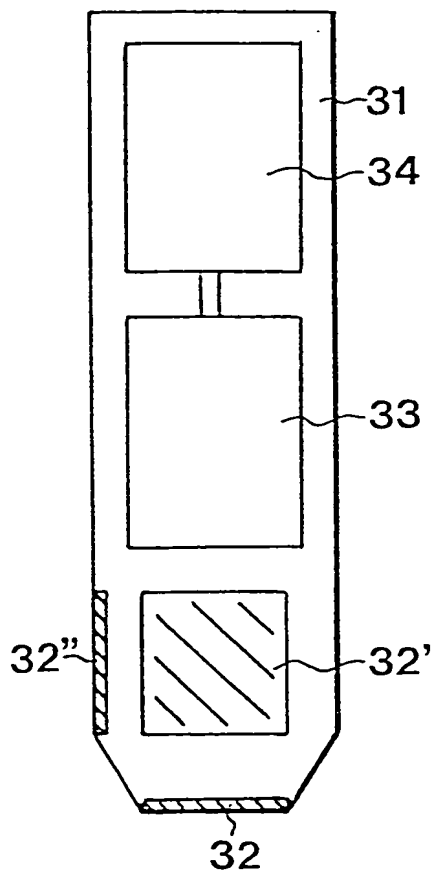


FIG 5

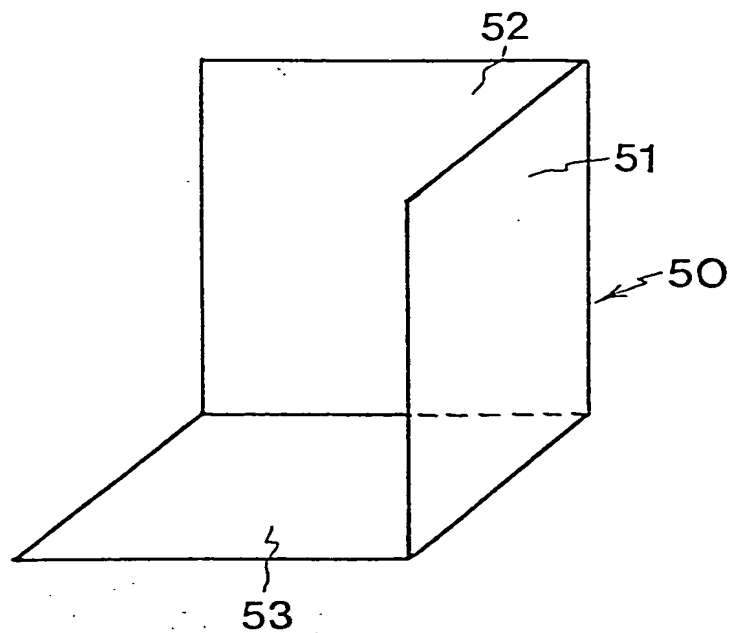
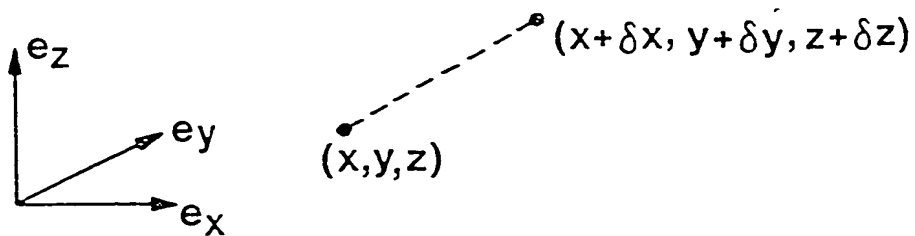


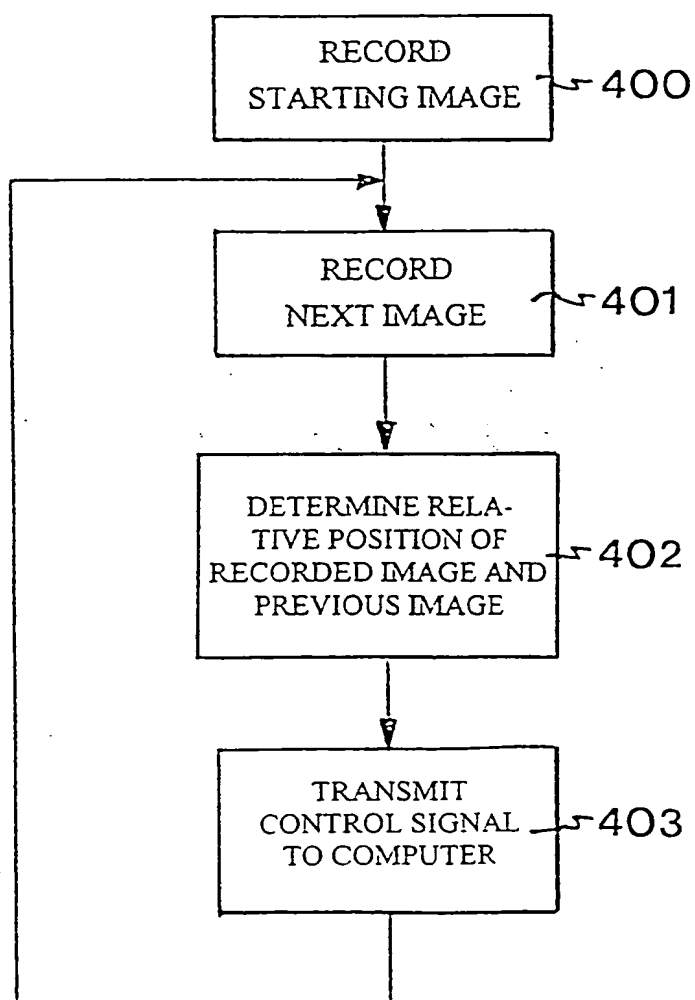
FIG 6



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FIG 4



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FIG 7

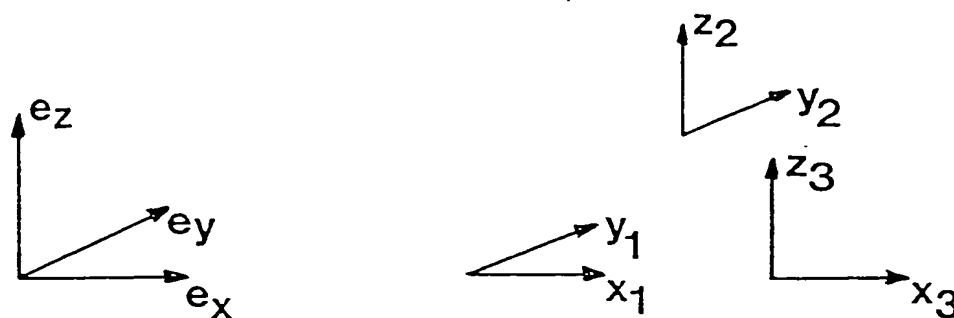
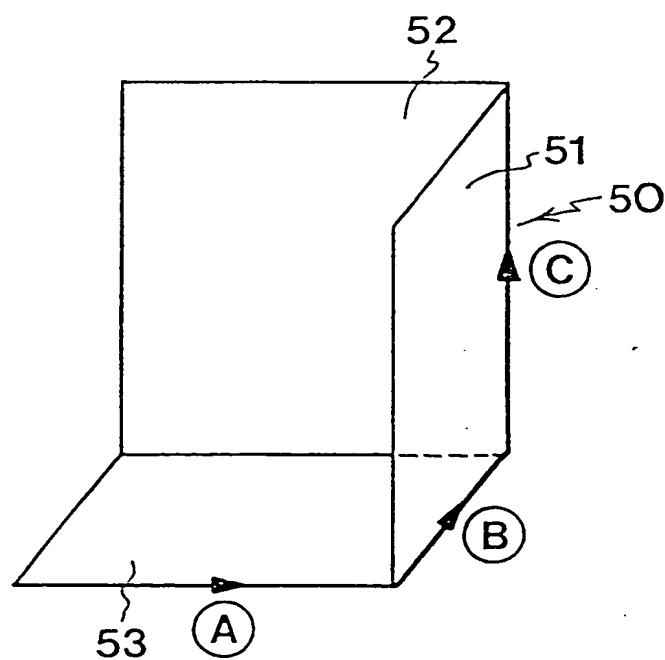


FIG 8



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## INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 99/00719

| <b>A. CLASSIFICATION OF SUBJECT MATTER</b>  |   |  |
|---|---|--|
| IPC6: G06F 3/033, G06K 11/18<br>According to International Patent Classification (IPC) or to both national classification and IPC   |   |  |
| <b>B. FIELDS SEARCHED</b>   |   |  |
| Minimum documentation searched (classification system followed by classification symbols)   |   |  |
| IPC6: G06F, G06K  |   |  |
| Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched   |   |  |
| SE,DK,FI,NO classes as above  |   |  |
| Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)  |   |  |
| WPI   |   |  |
| <b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>   |   |  |
| Category*   | Citation of document, with indication, where appropriate, of the relevant passages  | Relevant to claim No.  |
| A   | EP 0112415 A1 (INTERNATIONAL BUSINESS MACHINES CORPORATION), 4 July 1984 (04.07.84) | 1-25   |
|   | --  |  |
| A   | CN 1122925 A (YAN G), 22 May 1996 (22.05.96)  | 1-25   |
|   | --  |  |
|   | -----   |  |
| <input type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.  |   |  |
| * Special categories of cited documents:<br>"A" document defining the general state of the art which is not considered to be of particular relevance<br>"E" earlier document but published on or after the international filing date<br>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)<br>"O" document referring to an oral disclosure, use, exhibition or other means<br>"P" document published prior to the international filing date but later than the priority date claimed<br>"I" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention<br>"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone<br>"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art<br>"&" document member of the same patent family |   |  |
| Date of the actual completion of the international search   |   | Date of mailing of the international search report                             |
| 24 Sept 1999  |   | 28-09-1999   |
| Name and mailing address of the ISA:<br>Swedish Patent Office<br>Box 5055, S-102 42 STOCKHOLM<br>Facsimile No. +46 8 666 02 86  |   | Authorized officer:<br><br>Jan Silfverling/mj<br>Telephone No. +46 8 782 25 00 |

# INTERNATIONAL SEARCH REPORT

Information on patent family members

30/08/99

International application No.

PCT/SE 99/00719

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s)  | Publication<br>date                                      |
|---|---------------------|---|--|
| EP 0112415 A1                             | 04/07/84            | CA 1220582 A<br>JP 1723503 C<br>JP 4002968 B<br>JP 59119438 A<br>US 4675665 A | 14/04/87<br>24/12/92<br>21/01/92<br>10/07/84<br>23/06/87 |
| CN 1122925 A                              | 22/05/96            | NONE  |  |